PION PRODUCTION

ANALYZING POWERS FOR $\vec{p}p \rightarrow pn\pi^+$

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Our cross sections for the reaction $pp \rightarrow pn\pi^+$ measured in IUCF experiment CE03 showed surprisingly small contributions from non-s-wave contributions, even 10 MeV above threshold. As we communicated in a recent letter,[1] the deduced pion angular distributions were isotropic within experimental errors at the two lowest beam energies (294.2 and 300 MeV) and fully consistent with an s-wave πNN state. This outcome was expected for the lowest energy data taken (E_p=294.2 MeV) because 1.9 MeV above threshold the maximum pion kinetic energy in the three-body center-of-mass frame is only 0.82 MeV. With such low pion energies, the reaction amplitude should be dominated by s-wave πNN states, thus permitting the interesting link to the offshell features of the πNN vertex or low energy effective πN models. However, the relative weakness of non-isotropic contributions - e.g., the weakness of (allowed) contributions from the delta resonance - at 320 MeV bombarding energy was unexpected because the very similar reaction $pp \rightarrow d\pi^+$ shows strong non-isotropy for the pions, even close to threshold.[2] If confirmed, this is extremely useful because current theoretical models can be exploited as long as higher partial waves and contributions from resonances remain small enough so that the s-wave amplitude can be reliably extracted. Therefore, the conclusions of CE03 should be corroborated by a sensitive test. In proposing IUCF experiment CE38 we assumed that, as has been seen for $pp \rightarrow d\pi^+$, any significant p-wave contributions in $\vec{p}p \rightarrow pn\pi^+$ will produce measurable analyzing powers and permit a quantitative assessment of such contributions.

Experiment CE38 used the hydrogen-jet target in the IUCF Cooler. Several low luminosity test runs were performed in 1994 while IUCF developed higher luminosity polarized beams with low injection background. The $\vec{p}p \rightarrow pn\pi^+$ production run took place in late February 1995 after considerable improvements in polarized beam luminosity and background reduction had been achieved. We were able to measure kinematically-complete analyzing powers for $\vec{p}p \rightarrow pn\pi^+$ at 300, 320 and 330 MeV. Typically, spin-up

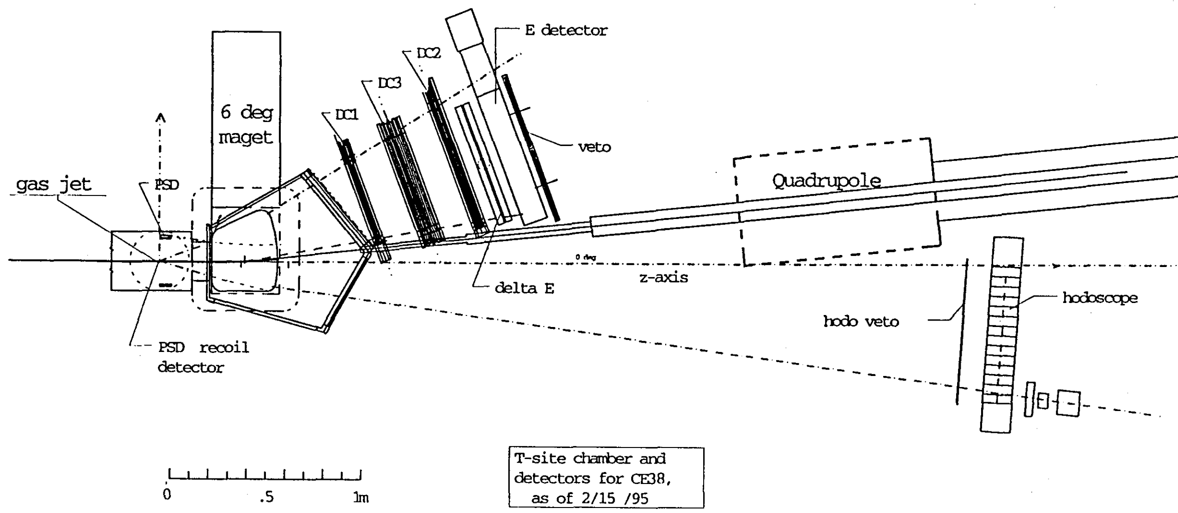

Figure 1. Layout of experiment CE38. The polarimeter primarily consists of the two identical recoil detectors covering $75° < \theta < 85°$, the forward E detector and the hodoscope. The hodoscope "veto" also served as a ΔE counter for the right arm of the polarimeter.

and spin-down cycles were alternated. Because of the limited running time available the preferred polarization sequence "zero-up-down" was used for a few runs only. In addition to the runs at 300, 320 and 330 MeV, short excitation-function runs were taken at 294, 297, 305, and 315 MeV in order to reproduce some of the total cross-section data of CE03. Data-taking was completed, and the analysis of this work is in progress.

Since the multiple-stage acceleration of the polarized beam can lead to polarization loss during acceleration, e.g., due to resonances in the Cooler Ring, we expanded the pp elastic-scattering luminosity monitor of CE03 into a polarimeter as seen in Fig. 1. The existing position-sensitive recoil detector (PSD) on the right side of the beam was complemented by a symmetrical PSD detector on the left, operated in coincidence with the 14-bar hodoscope, which now serves the dual purpose of neutron detector and elastic proton-scattering monitor.

Operation at high luminosity with Cooler kick injection had previously caused deterioration of our drift chambers, which need to be very close to the circulating beam. They are subject to high injection background because the T-site target location is directly downstream of the injection site on the ring. The recently improved (fast) kick injection has greatly reduced this problem. As an additional precaution the chambers were operated at a conservative (lower) voltage, which causes a slight drop in plane efficiency. To gain drift-chamber redundancy (and assure 100% proton tracking efficiency), a third position-sensitive drift chamber was built and inserted between the two previously used drift chambers. Otherwise, the apparatus was similar to that of CE03. The use of a constantly active polarimeter to monitor the beam polarization at full energy was facilitated by the very slowly varying and relatively high analyzing power of hydrogen (0.42 at 320 MeV). The typical beam transverse polarization at full energy was found to be $P_{-y} \approx 0.65$ for spin down and $P_y \approx 0.60$ for spin up, in agreement with intermittent cyclotron polarimeter measurements. Occasional changes in the polarization (as measured

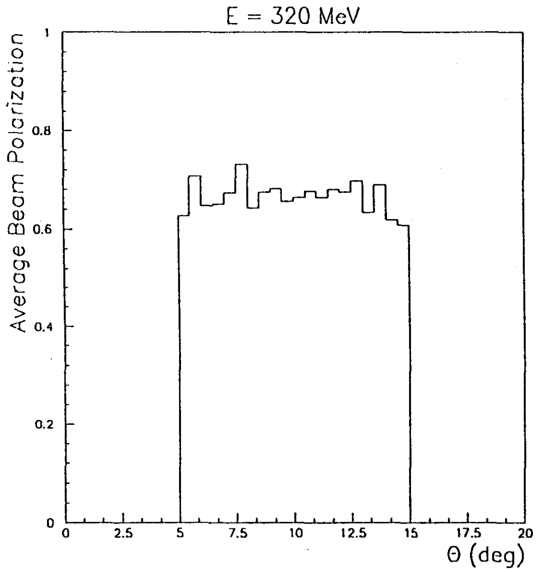

Figure 2. Beam polarization for pp elastic scattering at 320 MeV as measured with the CE38 polarimeter for a range of scattering angles.

at full energy) were seen. They were attributable to changes in the ion source, not to acceleration problems. Beam polarization, as measured with the polarimeter at various elastic-scattering angles, is shown in Fig. 2 for the 320 MeV run. We deduced typical polarized beam luminosities of about 0.7×10^{30} cm^{-2}s^{-1}.

Fast coincidence requirements and ray tracing of reaction protons from $\vec{p}p \to pn\pi^+$ to the target are reducing background counts to negligible levels. The much-reduced injection background permitted trouble-free detector operation throughout the experiment. The third drift chamber (consisting of an "x", a "y", and a "w"=45° plane) for the charged-particle arm provides redundant tracking information and now permits use of all recorded events, including multiple hits. The angular alignment and calibration of the charged-particle arm relative to the incident beam were confirmed to an accuracy of $\pm 0.3°$ by observing the sharp diffraction minimum at $\theta = 10°$ for ^{208}Pb(p, p)^{208}Pb elastic scattering as shown in Fig. 3.

The efficiency of the neutron hodoscope was determined by standard Monte Carlo calculations. The energy threshold was determined by scintillator calibrations with cosmic rays. Monte Carlo calculations show that the apparatus has significant acceptance for the reconstructed pion momentum and angles over its full phase space. Analysis of the pion cross sections is in progress.

1. W.W. Daehnick, *et al.*, Phys. Rev. Lett. **74**, 2913 (1995).
2. E. Korkmaz, *et al.*, Nucl. Phys. A**535**, 636 (1991); D. Hutcheon, *et al.*, Nucl. Phys. A**535**, 618 (1991); B.G. Ritchie, *et al.*, Phys. Rev. C **47**, 21 (1993).

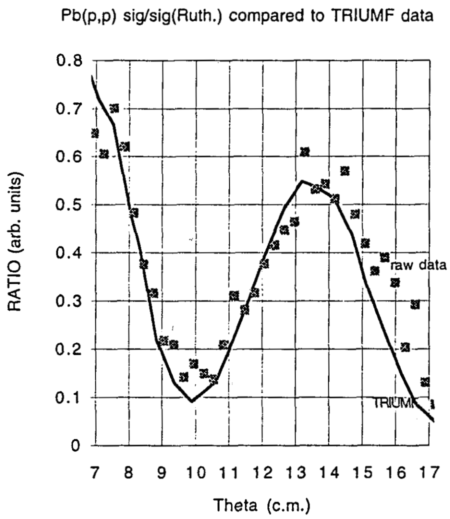

Figure 3. Raw data for elastic scattering of $^{208}Pb(p,p)^{208}Pb$ with the proton arm. The measurement was performed at the injection energy of 200 MeV to provide independent angular calibration for the forward detectors.

MEASUREMENT OF HIGH MOMENTUM TRANSFER REACTIONS ON THE INDIANA COOLER BY RECOIL DETECTION

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The system shown in Fig. 1, which has been described previously,[1,2] has been used to measure differential cross sections for the reaction $^{12}C(p,\pi^+)^{13}C$ by detection of the ^{13}C recoil ions. Measurements were made at extreme forward and backward angles at bombarding energies of 166, 294, and 330 MeV. The system consists of a parallel grid